Abstraction and use of groundwater to heat buildings in a hard rock urban environment - revised AI

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1. Introduction

In order to turn more efficient the heating of class rooms in the lower floor of the old building of the University of Évora (a XVI century building), five drillings were organised inside the area of the university (Figure 1). The purpose was to use the temperature differential of groundwater in relation to air, by means of a heat exchanger, and use this process to heat the rooms using less energy, turning the heating process less expensive.

The wells were drilled in fractured rocks (gneisses), and the purpose was to locate them at least around 100 m one from each other, whilst trying to have a hydraulic connection in-between. From the five initial wells, four were successful in terms of productivity, but just two of them (RA1 and RA2) proved to be hydraulically connected. The wells were equipped with screens for all their drilled depth (100 m), except for the first six meters and some two or three pipes of six meters each, to allow space for the installation for submersible pumps. The length of the installed screens guarantees a good efficiency of the system.

In the wells with no connection, the heating system can work using each single well for abstraction and injection, but the process is much less efficient than in the cases where interaction between wells is possible through the rock's fracture network.

2. Results and analysis of the flow tests

During the flow tests it was possible to confirm the impressions registered during the drilling works: wells RA3 and RA4 don't have any connection between them or with each of the other ones (RA1 and RA2), but RA1 and RA2 are hydraulically connected underground, at least by one fracture.

The results of the flow test in RA3 are shown in figure 2. It's possible to see that to values higher than 0.56 L/s the drawdown becomes too high.

In relation to the flow test in RA4 (figure 3), the result shows that the well has very low abstraction capacity. At 0.17 L/s the water level was around 60 m deep and with 0.25 L/s the water level was going quickly down when the flow test finished, after a total time of 24 h.

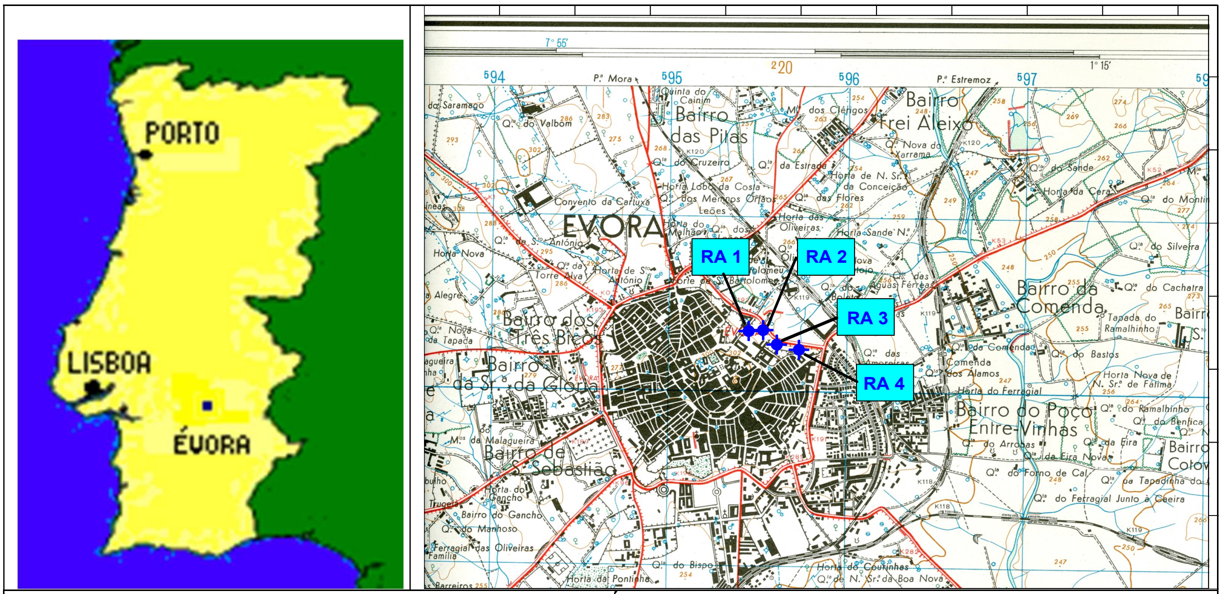


Figura 1 Position of the wells RA1 to RA4 in the city of Évora, Portugal

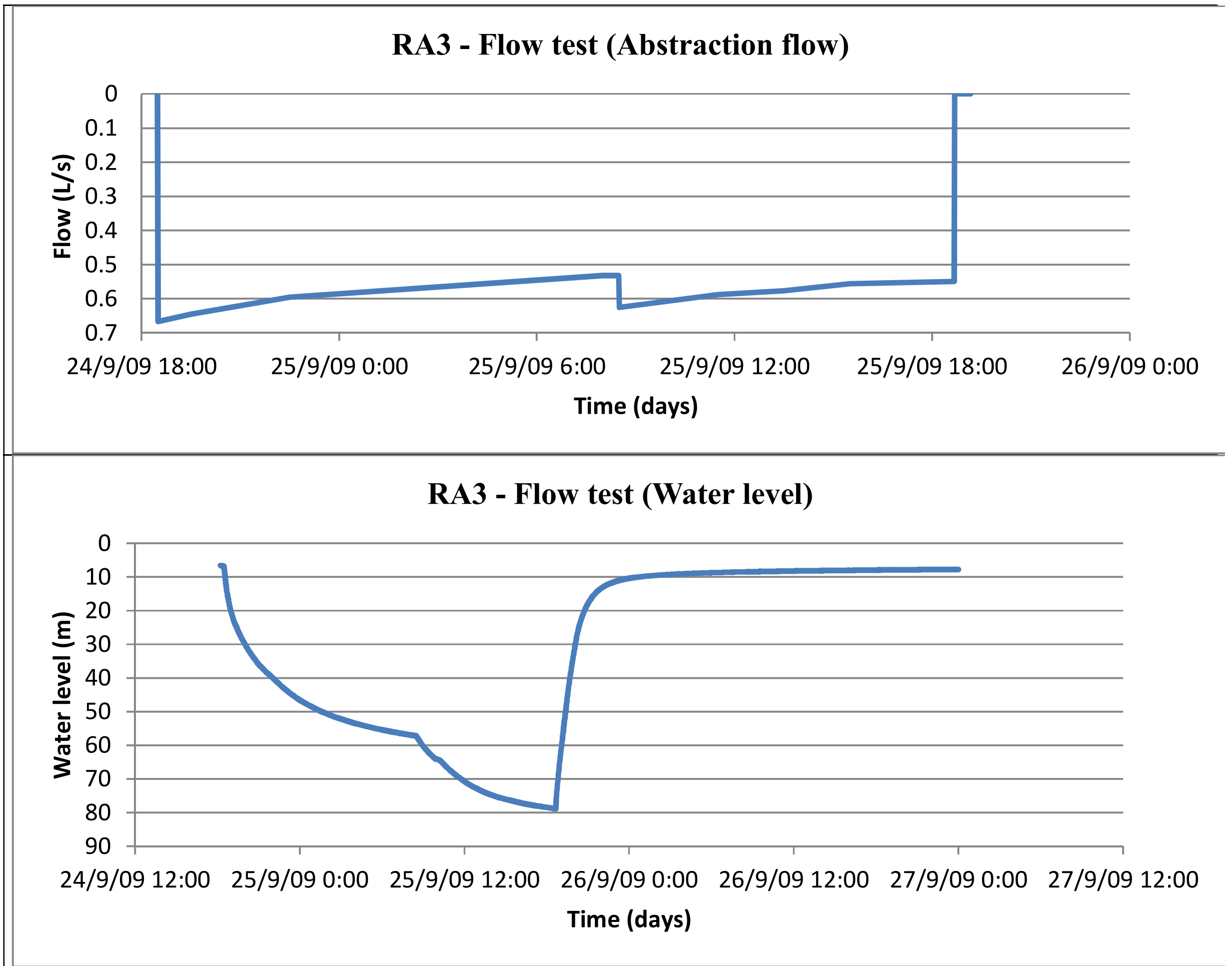


Figura 2 Graphics showing the abstraction flow during the flow test (top) in well RA3 and the water level (down) in the same well; observe that the time scale in both graphycs is different

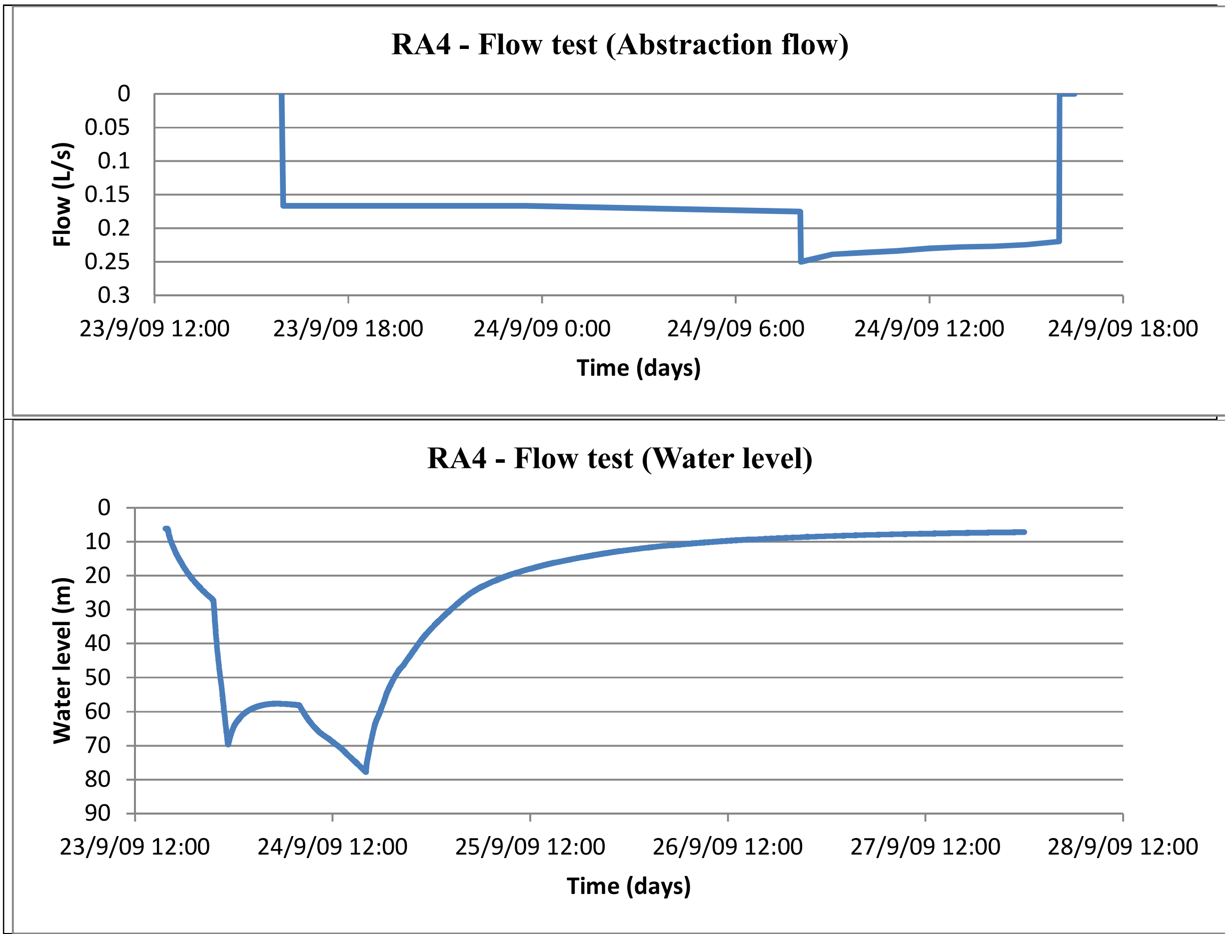
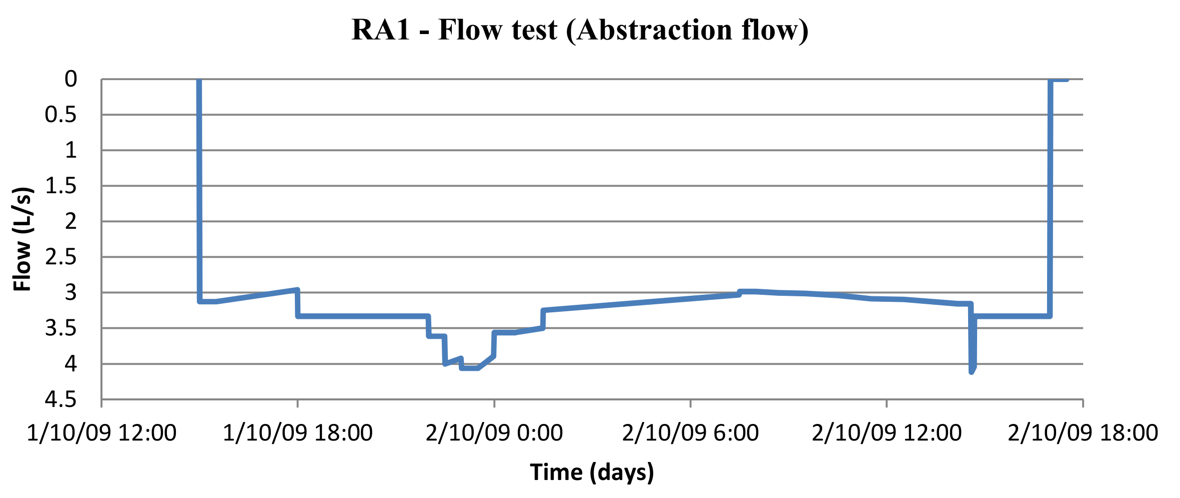
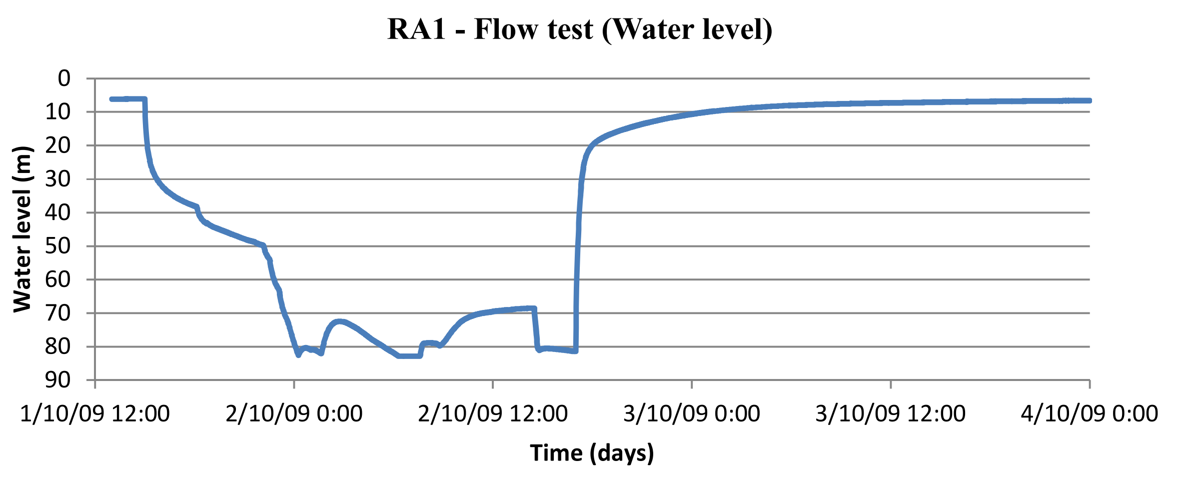


Figura 3 Graphics showing the abstraction flow during the flow test (top) in well RA4 and the water level (down) in the same well; observe that the time scale in both graphycs is different

In relation with RA1, the flow test involved successive shifts in the abstraction rates (figure 4), in order to understand how much water could be abstracted from it. The maximum abstraction rate was 4.17 L/s, with the water level under 80 m deep (middle graphic in figure 4). The lower graphic in the same figure shows the behaviour of the water level in RA1 during the flow test in RA2 (see also figure 5), abstracting 2.78 L/s in RA2. In the beginning it's possible to see the influence of RA2 on RA1 during the flow test (a drawdown), then the level went up to the ground level when the flow abstracted from RA2 was injected in RA1. When the water reached the ground level, part of the water injected spilled from RA1. By the difference between the abstracted water in RA2 and the spill flow from RA1, it was possible to determine that 1.58 L/s were passing underground from RA2 to RA1.

The flow test in RA2 was done 3 times, and one of them (the last one) has gone to almost 3.89 L/s (see first graphic in figure 5). The second graphic of figure 5 shows the water level in the second flow test, using a pump that just withdraw a maximum of 2.22 L/s. The water level was going to a deep of around 70 m, so a new and more powerful pump was installed and allowed the third flow test, beginning at almost 3.89 L/s, which caused a strong drawdown (see graphic 3 in figure 5). Near the 90 m level, the flow was changed to 2.78 L/s, which allowed to stabilise the water level





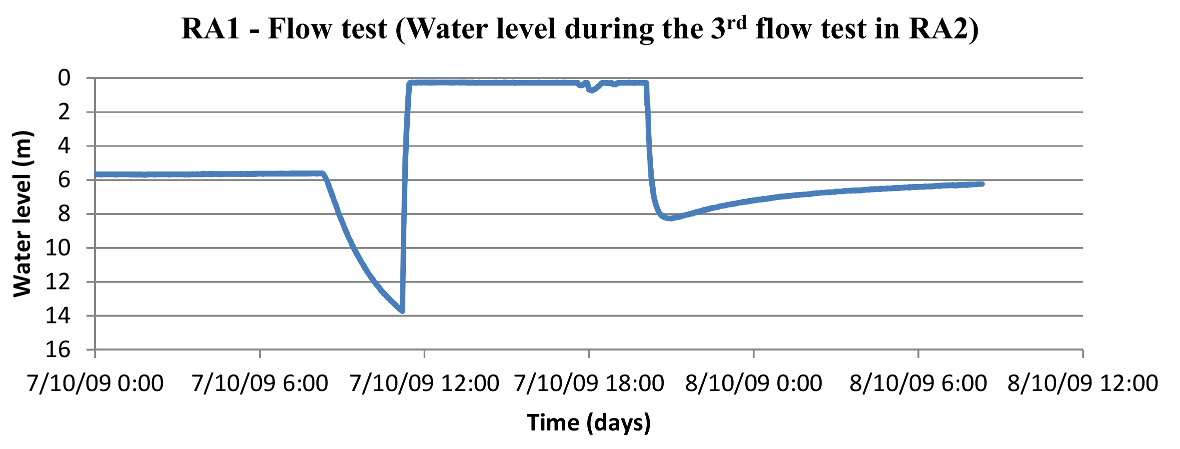
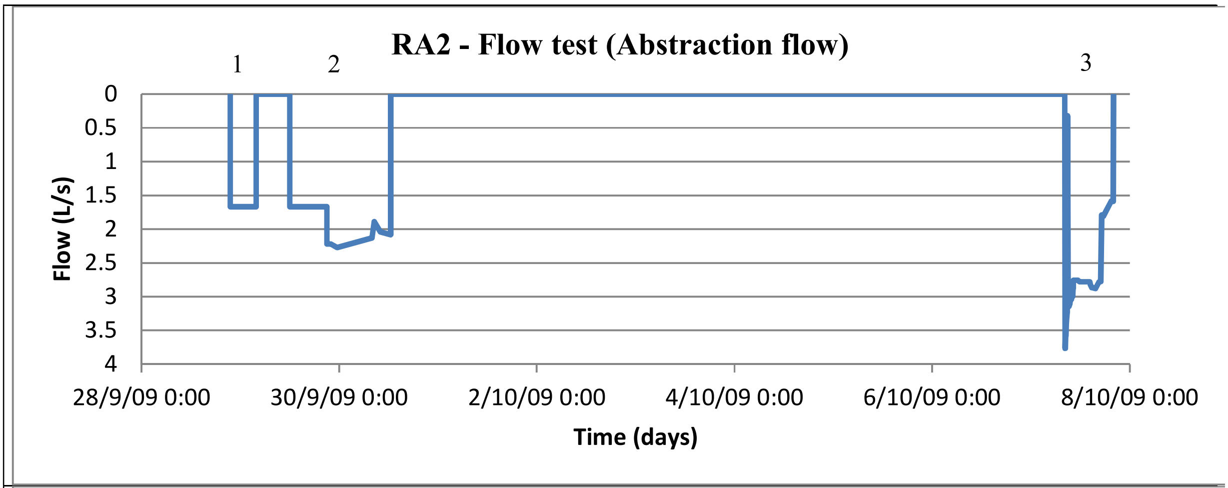
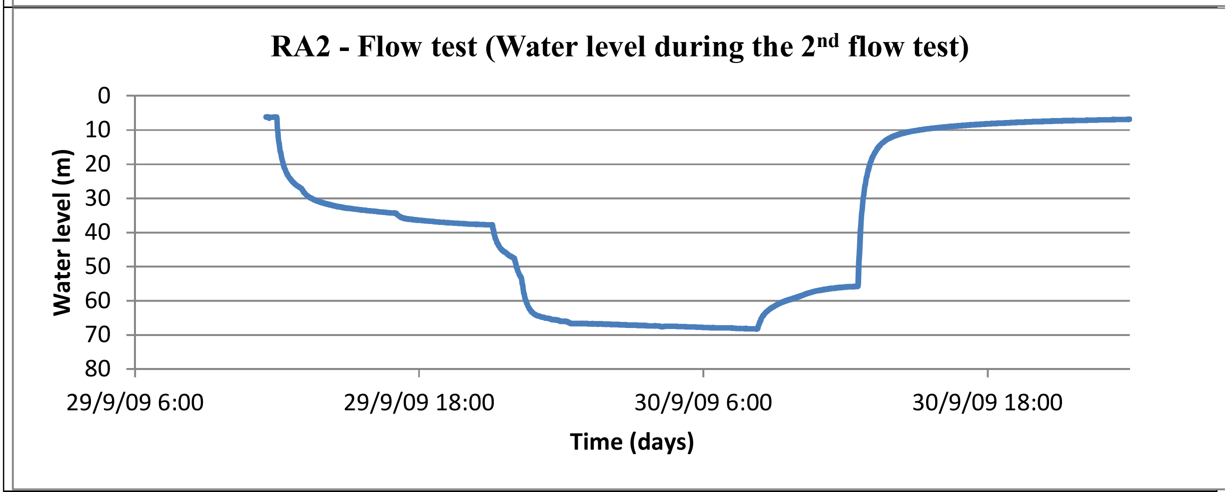
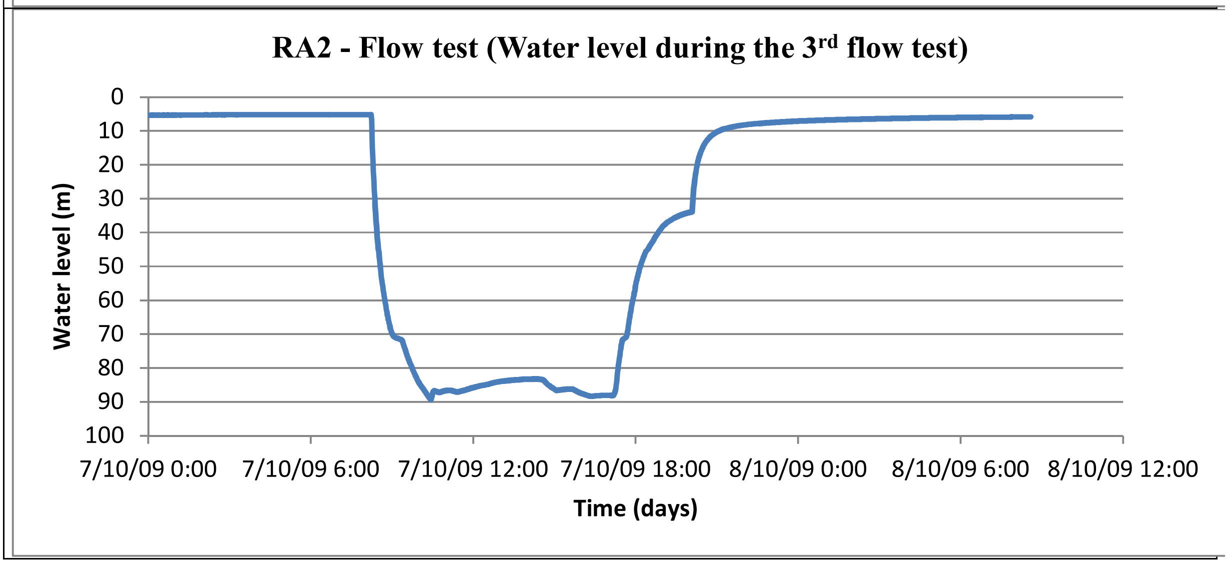


Figura 4 Graphics showing the abstraction flow during the flow test (top) in well RA1 and the water level in the same well (middle); the lower graphic shows the behaviour of water level during the flow test in RA2, including reinjection of water from RA2 in RA1; observe that the time scale in each graphyc is different


RA2 - Flow test (Abstraction flow)
1
2
3
Flow (L/s)
0
0.5
1
1.5
2
2.5
3
3.5
4
28/9/09 0:00
30/9/09 0:00
2/10/09 0:00
4/10/09 0:00
6/10/09 0:00
8/10/09 0:00
Time (days)


RA2 - Flow test (Water level during the 2nd flow test)
Water level (m)
0
10
20
30
40
50
60
70
80
29/9/09 6:00
29/9/09 18:00
30/9/09 6:00
30/9/09 18:00
Time (days)


RA2 - Flow test (Water level during the 3rd flow test)
Water level (m)
0
10
20
30
40
50
60
70
80
90
100
7/10/09 0:00
7/10/09 6:00
7/10/09 12:00
7/10/09 18:00
8/10/09 0:00
8/10/09 6:00
8/10/09 12:00
Time (days)

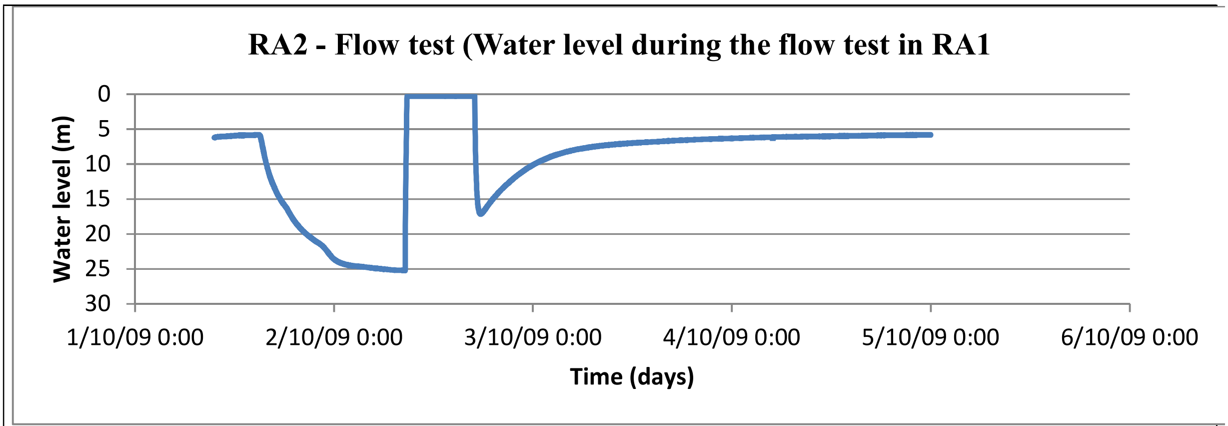


Figura 5 Graphics showing the abstraction flow during the flow tests 1, 2 and 3 (top) in well RA2 and the water level in the same well for two flow tests (2nd and 3rd graphics); the 4th graphic shows the behaviour of water level during the flow test in RA1, including reinjection of water from RA1 in RA2; observe that the time scale in the different graphycs is different

around the 90 m deep. Graphic 4 in figure 5 shows that, during the abstraction in RA1, the water level has gone, in about 4 h, from 5 to 25 m deep (with an abstraction flow in RA1 of around 3.33 L/s). By then, the water abstracted in RA1 was injected in RA2, which caused the rise of the water level to the top of the well. By then, 1.86 L/s were passing from RA1 to RA2.

3 Final remarks

From the interpretation of the flow tests and considering the future use of these wells, it was possible to confirm that wells RA1 and RA2 can be used to abstract fresh water to use in the heating pump and to introduce the same water in the other one, being this from RA1 to RA2 or from RA2 to RA1. The flow tests showed that the transfer of flow from RA1 to RA2 is slightly higher (1.86 L/s) than from RA2 to RA1 (1.58 L/s).

For the other two wells (RA3 and RA4), the only possibility is to abstract and introduce the water in the same well (closed circuit), which is much less efficient than the situation of RA1 and RA2.

For the moment, just the first option (RA1 and RA2) was used.

Table 1 shows the maximum abstraction flow recommended for each productive well. As RA1 and RA2 are hydrogeologically linked, in production the maximum abstracted water must be 1.86 L/s in RA2 and 1.58 L/s in RA1, due to the reinjection rates calculated during the study.

Table 1 Well production

Well	Maximum flow (L/s)
RA1	3.06
RA2	2.64
RA3	0.50
RA4	0.17

Note: The water transfer in the aquifer from RA1 to RA2 is higher (1.86 L/s), than the transfer from RA2 to RA1 (1.58 L/s).

Other issue related with this topic is that the actual legislation in Portugal doesn't mention this water use: legislation applies for groundwater consumption, but this water is only used and reintroduced in the aquifer, so there is no consumption. Once the normal groundwater temperature in this region is between 18 and 20 ºC and the same water is reintroduced with a temperature of around 28 ºC, the Portuguese authorities wanted to know what would be the effects of the reintroduction of water at 28 ºC on the living organisms in groundwater, or, at what point would the heat be considered pollution.

The wells were finally approved when it was explained that this technique was experimental, to be used inside the University, in a kind of aquifer that represents ¾ of Portugal (hard rocks), and affecting just a very small area. This project led the Portuguese Agency for the Environment (APA) to send to the government the information that Portugal needs urgent legislation about this kind of groundwater use and, accepting this experience as an experimental study, APA authorised the development of this project.